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## DISCUSSION OF PARTICLE SIZE OF INSECTICIDES AND FUNGICIDES

There has been considerable confusion with reference to methods of determining particle size and just what is meant when a certain particle size is referred to. At the suggestion of Mr. W. H. White the idea of having those interested in this matter get together for a rather full discussion was presented at a meeting of Division Leaders in Dr. Annand's Office. The idea was well received and was approved by Dr. Annand who designated Dr. Bishopp to arrange for the discussion. Accordingly arrangements were made for this on April 14, 1944, in the auditorium of the Bureau of Plant Industry, Soils & Agricultural Engineering.

Representatives of all of the Research Divisions of the Bureau and several of the Control Divisions were in attendance, also several representatives from the Bureau of Plant Industry, Soils & Agricultural Engineering, the War Food Administration, and Food and Drug Administration. The attendance was approximately 55. The entire afternoon from 1:00 p.m. to 4:20 p.m. was spent in the discussion.

Attached are a copy of the program and an abstract of the discussions.

## DISCUSSION OF PARTICLE SIZE OF INSECTICIDES AND FUNGICIDES

Auditorium, Bureau of Plant Industry, Soils & Agricultural Engineering, Beltsville, Md., Fri., Apr. 14, 1944, 1:00 p.m.

Many questions have arisen with reference to particle size of insecticides, fungicides and diluents, and it is desirable to bring together personnel of the Bureau of Entomology and Plant Quarantine for an informal discussion of problems in this field and, if deemed necessary, to undertake special work to close gaps in our existing knowledge. Members of the staff of the Bureau of Plant Industry, Soils & Agricultural Engineering dealing with the use of fungicides and with the development and use of spray and dust equipment are invited to participate in the discussion.

The conference is to begin promptly at 1:00 o'clock and continue until 4:15.

The following general topics are suggested for discussion:

F. C. Bishopp, Chairman

1. Definition and determination of particle size, especially as applied to dust, including demonstration of air permeation machine.  
C. M. Smith and E. L. Gooden
2. Production of fine dusts . . . . . C. M. Smith
3. Specifications as regards particle size . . . . . C. M. Smith
4. Particle size as applied to aerosols, including smokes  
Randall Latta and L. D. Goodhue
5. The relation of particle size to efficacy  
"Dust and Sprays" E. H. Siegler, N. F. Howard and E. R. McGovran  
"Aerosols" . . . . E. R. McGovran, Randall Latta and L. D. Goodhue
6. Field problems involving particle size of insecticides and fungicides  
(dustability, adhesion, separation of diluents, etc.) General discussion
7. What can be done to accelerate and improve investigations relating to particle size? General discussion

It is desirable that representatives of all the Research Divisions of the Bureau of Entomology and Plant Quarantine dealing with insecticides be present, and it is felt that practically the entire research staff at Beltsville may profit by attending this conference.

It is desired that anyone having research results or practical experience bearing definitely upon the question of particle size be prepared to present his information in concise form. Although it is our desire not to limit the discussion, obviously remarks must be rather brief and to the point. Individuals contributing to given topics should not exceed 15 minutes. (Lanterns available.)



1. Definition and determination of particle size, especially as applied to dust, including demonstration of air permeation machine - By C. M. Smith and E. L. Gooden.
2. Production of fine dusts - By C. M. Smith
3. Specifications as regards particle size - By C. M. Smith

#### Abstract of Remarks

Everyone knows that insecticidal sprays consist of small droplets, and insecticidal dusting materials are almost impalpable powders. It is important to determine by careful laboratory tests whether the degree of effectiveness depends on particle size, and when it is found to do so, practical tests should follow in order to determine whether attempts to produce a spray or dust of some optimum particle size is justified.

The following discussion is devoted to powdered insecticides. The Division of Insecticide Investigations has studied particle size of powders for years, and published surveys of lead arsenate, calcium arsenate, paris green, sulfur, sodium fluoride and sodium fluosilicate.

Sieving is usually the first recourse in judging the fineness of a powder. There is available a U. S. Standard Series of wire sieves, which have square openings the diameters of which form a geometrical series as do the notes in a musical scale. The size of opening is rather closely specified, but because the size of wire is allowed to vary quite a bit the designation by number of meshes per inch does not mean much. High mesh numbers are ordinarily taken to indicate fineness, but in this series one sieve could legitimately have a mesh number lower than the next coarser one! All members of the Bureau are urged to quit speaking of a 200 mesh sieve, and to refer to it properly as a number 200 sieve. The finest standard sieve made at present is the No. 400, which has openings 37 microns in diameter. While the finest sieves are usable with some of the coarsest insecticides, the quantity of many standard insecticides retained on them is so little as to make a particle-size analysis by sieves impossible. Many lead arsenates for instance will pass practically completely through the No. 400 sieve if wetted with alcohol. Other methods of determining particle size are evidently necessary.

Our experience has been confined to three methods--microscopic measurement of linear dimensions, estimation of "effective diameters" by observations of rate of fall of the particles through air or a liquid, and estimation of "surface-mean particle diameter" by the method known as air-permeability or air-permeation. The first two of these reveal the relative proportions of all the various sizes of particles present, but have some drawbacks, and do not readily furnish the average particle size which most persons prefer to consider. So, Mr.

E. L. Gooden was led to consider more direct methods of estimating average size, and developed an apparatus which judges fineness by the resistance which a packed column of powder offers to the passage of air through it. Considerations of the concept of a representative "diameter" for an irregular particle, and of an average of a multitude of these to represent the fineness of a powder, led us to reject all numerical averages because of the impossibility of reaching a decision as to the total number of particles in a given quantity of powder, the apparent number depending upon the degree of resolution possessed by the method of observation used. Regular polyhedrons, such as the cube, and including the limiting sphere, have well recognized single-valued diameters which are equal to the quotient obtained by dividing the surface area into six times the volume. This concept can readily be extended to include a particle of any irregular shape, or an aggregate of particles forming a powdered insecticide, because for any mass there is always a total volume and a total surface. The machine developed by Mr. Gooden gives this particular average, which is technically called the "surface mean diameter." A self-calculating device enables the operator to read the average diameter directly, after a few minutes in the case of coarse powders and after about 1/2 hour with very fine ones. The machine was patented by Mr. Gooden and the Fisher Scientific Company of Pittsburgh have developed a commercial model which is now being sold under license from the Secretary of Agriculture. Five home-made machines are being used in the Bureau's laboratories at Beltsville, Md.; Vincennes, Ind.; Columbus, Ohio; Yakima, Wash.; and Orlando, Fla. Surveys of insecticidal sulfurs, sodium fluoride, and sodium fluosilicate made with this instrument have been published, and one concerning calcium arsenate is now in press. Considerations relating to its use with cellular material like dorris and cube powders have also been published.

We are not able to speak authoritatively concerning what might be done in the way of altering the particle size of insecticides as now produced. It can be controlled to some degree during the chemical stage of manufacture, as demonstrated by the Sherwin-Williams Co. with their basic copper arsenate. Grinding will work in many cases but certainly carries with it a considerable cost item. The micro-nizer mill is effective with some materials, having given good results with phenothiazine, but having failed to accomplish anything with dorris or cube powders. Perhaps greatest dependence is to be placed on the use of air-separators.

If the particle size of insecticides proves important enough to warrant specifications, careful thought should be given to the type thereof. There is no point in specifying a size distribution matching that of some particular lot known to have been satisfactory, unless the importance of the distribution has been thoroughly demonstrated. In our opinion, the best practice would be to specify a limit for the quantity of material failing to pass a particular fine sieve, say the No. 200 or No. 325, and require in addition that the average particle size as determined by air-permeation be within definite limits.



#### 4. Particle Size as Applied to Aerosols, including Smokes.

By Randall Latta

In the study of particle size it has been the endeavor to obtain small particle size. Practically all methods used heretofore, have been to take a solid or liquid and break it into finer and finer particles. In our work on thermal generated aerosols or smokes we will attack it from the bottom side. We will take liquid material and turn it into particles which are visible as a smoke. The optimum range indicated by work on liquefied gas aerosols is below that produced by any other method and it is above the smoke stage, so that the situation as we see it is that the liquefied gas aerosols are within the optimum range and all methods will try to work down into that range from above. Thermal generated aerosols start below and try to work up into it.

Shown by slides: A sample of medium atomized spray of lead arsenate.

A fine atomized oil spray. The particle size range is from about 10 microns diameter up to about 35 microns in diameter.

A coarse atomized spray. Notice absence of smaller particles there.

Particles of sulfur dust.

Liquefied gas aerosols in which particles range between 10 to 15 microns in diameter.

Thermal generated aerosol. Some particles are as large as those in the liquefied gas method.

Screening smoke in which all the particles are approximately the same size and all about 1 micron or less in diameter.

Cigarette smoke. These are all dry particles but similar to the screening smokes.

In order to have some comprehension of the comparison between sizes of particles with something that we see every day, we have made a rough chart. The slides are approximately 500 magnifications, so we have the pictures on the chart to scale. You can see relation between insects as small as aphids and particles that come in contact with them.

One interesting thing you become aware of in our thermal generated aerosols, is that we started out with a screening smoke. You can see smoke because of the large number of particles, but when you raise the size of the particles you no longer see the smoke. A spray which has many times the volume of material still is practically invisible. You can take small fractions of the material in smoke form and it completely obscures objects short distances away. This is explained when you compare volumes of particles.

An interesting thing that Mr. Potts found is shown in a table calculated to show the dispersion of particles over a flat area according to their size.

We have borrowed heavily on information from a unit in the N. D. R. C., which has been developing smoke generators for the Army. Their field laboratories have worked out methods of determining particle size. Screening smokes are made from oil. Therefore, the particles are spherical and can be measured under a microscope. The Columbia University Laboratory of the N. D. R. C. has developed a coating for slides which allows each particle to retain its identity and shape. The diameter of the particles as they appear on the slide is greater than that of the original droplet, since there is a certain amount of spread as the particles contact the slide. This spread can be calculated by determining the curvature of the drops on the slide and from this figure the diameter of the original spherical droplet can be calculated. For our purposes we did not need a coating material of the quality developed by the Columbia University group. The chemists in Insecticide Investigations have prepared a number of solutions for us which were tested. The best of these was selected and is quite simple to use.

The N. D. R. C. Laboratories have also developed other methods for calculating the particle size in screening smokes. For particles under 2 microns in diameter an apparatus is used which has a constant light ray source operating into a photoelectric cell. The particle size is calculated by the interference occurring in this light ray.

A third method is to use the sun. If the sun is viewed through a cloud of smoke the particle size, provided it is fairly uniform, can be calculated from the halo produced.

Another method of measuring particle size is a cascade impactor. We have received one and have been testing it. It works upon the principle of trapping particles on a slide at a given rate of flow. Material is pulled through a series of apertures in the instrument and at each stage is impinged on a glass slide. The velocity through each succeeding aperture is greater due to the reduction of pressure on the lower side, and a size group is deposited out at each stage.

Question: How can you control formation of size particles?

The material is first converted into the vapor state. Then it is condensed into particles by cooling, which makes the smoke that you see. The mixture of air at the point of condensation is apparently a vital factor in the determination of particle size. The greater the dilution with air the smaller the particle size. From the standpoint of creating screening smoke this dilution wants to be considerable. By controlling dilution the particle size can be increased to a limited degree.



#### 4. Particle size as applied to aerosols, including smokes

By Lyle D. Goodhue

The range of particle sizes in the aerosol lies between those of particles too large to float in air and those of gas molecules that stay suspended indefinitely. There is no sharp demarkation for the upper particle size limit for aerosols but particles in this range must form a colloidal system, at least temporarily. Particles having a radius of 1 micron ( $10^{-4}$  cm) settle 43 cm. per hour. With a size of  $10^{-2}$  cm the settling rate is 4320 meters per hour, and particles of that size should be considered outside the colloidal range.

Liquefied gas aerosols:- We expect the effect to take place in the first minute. Aerosols produced by the liquefied gas method can vary greatly in particle size but this is easily controlled by the amount of nonvolatile material in the liquefied gas solution. About 15% nonvolatile is near the optimum amount for houseflies. A wide range of particle sizes always occurs in the aerosol produced by the liquefied gas method.

A method of determining the settling rate in air was briefly described. (Goodhue, Ind. Eng. Chem. 34, 1456, 1942). This consists of catching a dyed aerosol in glass plates which are uncovered at regular intervals and determining the amount of deposit colorimetrically.

The following particle-size distribution was calculated from one of these settling curves:

<u>Radius in microns</u>	<u>Percent</u>
Above 8	16
8 - 5	20
5 - 4	16
4 - 3	12
3 - 2	14
Below 2	22

Slide showed a very wide range of particles. Large particles kill quickly. Fine particles float longer and spread out to kill insects in protected places.

Question: When is an aerosol really an aerosol and when is it a mist?

Answer: It is difficult to say where one leaves off and the other begins. Anything above 20 microns I would say begins to be a mist.

## 5. The Relation of Particle Size to Efficacy

### "Dusts and Sprays"

By E. H. Siegler

Insect and insecticides. The codling moth was the test insect used in our studies; sprays were used in the work herewith reported. The data are based on experiments conducted several years ago in which comparative tests were made of lead arsenate, calcium arsenate, paris green, cryolite (synthetic), and phenothiazine.

Feeding habit of codling moth. The codling moth is quite a different type of insect from others to be discussed today. It feeds differently and we have no opportunity to measure the quantity of poison ingested. The only objective of the newly hatched larvae is to cut an opening through the skin of the apple and to tunnel into the flesh where the real feeding is commenced. It casts aside the skin particles and poisoning is therefore more or less incidental. Some of the insecticide may be mechanically dragged into the entrance hole and consumed with the flesh.

Factors in particle size-effectiveness relationship. In considering the relation of particle size to toxicity there are 3 principal factors involved: (1) physical, (2) chemical, and (3) physiological. The physical is concerned with the size of the particles before and after ingestion, the chemical with the action of digestive enzymes on the particles in the alimentary tract, and the physiological with the functions of the mouth parts, alimentary tract, etc.

The following is quoted from The Journal of Pharmacology and Experimental Therapeutics, Vol. XIX, April 1922, No. 3, pages 258-9:

"During a study conducted in the Bureau of Chemistry it was found that marked and significant variations occur in the toxicity and potency of undissolved arsenious oxide. This lack of uniformity is due to the difference in the average size of the particles constituting each preparation. One finely-divided preparation of arsenious oxide consumed by rats in their food proved to be five times more toxic than one of the coarse preparations. One finely-divided preparation administered by a stomach tube to rabbits was eight times more toxic than



another, but coarser, preparation. In the case of chickens, however, the differences observed were not so great, because of the fact that chickens have gizzards in which, presumably, the larger particles are ground."

How many of us know whether the insects we are working with have gizzards and the possible role of this organ in reducing particle size of insecticides?

Question: Does the codling moth have a gizzard?

Answer: No, it does not; lepidopterous larvae do not have gizzards. The codling moth might possibly be more readily controlled if it had.

Insecticide fractions. In our investigations the several insecticides, except lead arsenate, were divided into 6 or 7 fractions by means of a centrifugal air classifier. Several of the fractions were discarded so as to get coarse, medium and fine fractions with as little overlapping as possible. There was, however, considerable overlapping. On the other hand, the mid-size (the size which divides each fraction into two equal parts by weight) of each fraction was distinctly different from the others.

With each test complete data were obtained for:

- (1) Mid-size and range in size for each fraction--fine, medium and coarse--for each of the 5 insecticides (fine and coarse only for lead arsenate).
- (2) Chemical analysis of each fraction.
- (3) Spray deposit on plugs mmg./sq. cm.
- (4) Toxicological results.

Lantern slide. The illustration on the screen shows the comparative size of the mid-size particles for each fraction. Slightly higher mortalities were obtained with the so-called medium fractions which for the different insecticides ranged for the mid-size from 5 to 15 microns. The coarse fraction of phenothiazine, with a mid-size of 45 microns, was considerably less effective than the medium and fine fractions. Forty-five microns is not unusually large since this size would just about pass through a number 325 mesh screen. As judged by the toxicity tests, however, this size is too large for best results with phenothiazine against the codling moth. It may be that the larvae



do not readily ingest a lethal load of this size or it may be that the digestive enzymes do not react on this size as effectively as is desirable from the standpoint of kill.

Question: Why are the medium fractions more effective than the fine fractions?

Answer: It is not possible to give a proven answer to this question. The mandibles of the insect may be compared with the scoop-bucket of a steam shovel since the opposing mandibles rasp back and forth in a manner somewhat like that of the hinged bucket as it scoops its load. If the particles are too small they cannot be readily loaded; the same is true of very large particles. The mid-size is the one that seems to be loaded into the mouth parts of the codling moth in amounts greater than those obtained with smaller sizes.

In a number of experiments conducted by various entomological workers, it has been reported that commercial "ultra" or superfine lead arsenate was not as effective as standard lead arsenate.

Optimum particle size for each insecticide and insect. We believe that there is probably an optimum particle size for each insecticide and insect species; this theory may even extend to instars of the same species.

The optimum size is at present unpredictable. It does not necessarily follow that small-size particles of insecticide B would operate to best advantage because this was true of insecticide A. The number of factors involved (physical, chemical, and physiological) are so complex that nothing short of substantial data will give reliable conclusions.

## 5. The Relation of Particle Size to Efficacy

### "Dusts and Sprays"

by N. F. Howard

Last summer we used sulfur as a dust approximately 5 microns and 10 microns on two experiments for the control of leafhoppers on potatoes. In neither experiment was there any difference in kill. In a third experiment on beans for the control of the same insect, using the same powders, reduction of leafhopper nymphs was greater in the case of the larger particle sizes. In this experiment we used coarser particles. They are the only data we have that are absolutely on particle size.

Working with derris we found that the smaller particles in a series ranging from 19 to 6 microns were more toxic to Mexican bean beetle larvae than those in the upper range. Also measuring of the results of amount of feeding done by the bean beetle showed more feeding was done when material was of larger particle size--just the reverse of the mortality<sup>1/</sup>.

Another investigator at our laboratory worked with pea aphids and bean beetle larvae. He found that the finer the mill of the derris root the greater the mortality that was obtained with both of these insects. Also, the finer the particle size of the diluent used in these fine powders the greater the mortality.

We couldn't make a formula hold for Barbasco and Cube. It had worked with the original samples we had and we believe the reason was that we didn't know the toxic ingredients other than rotenone. Also we didn't know exactly how the rotenone-bearing roots killed insects we were working with. My conclusion is that rotenone-bearing roots are not good media for study of the particle size, because we do not yet know enough about the roots to evaluate the particle size. We get tangled up in other factors.

Remarks after Dr. McGovran's paper: In insecticide tests of this nature, I think you are safe in using the bean beetle. It does not ingest all the surface of the leaf. In each instance we should know how the insect feeds before starting to work with it in a study of particle size.

<sup>1/</sup>Reference: Jour. Econ. Ent. Vol. 37, pp. 63-69, Hutzell and Howard.



## 5. The Relation of Particle Size to Efficacy

### "Dusts and Sprays"

By E. R. McGovran

This investigation was made sometime ago. Mr. Cassil of the Division of Insecticide Investigations separated the various particle sizes which were used. It is a simple matter to say we have a sample of average particle size of 12 microns but another thing to get material that has all the same size particles in it. There was some variation in these samples but not nearly as much as in an ordinary commercial sample. In the 22 micron fraction the size ranged from 25 to 60 microns. There is another point that comes in here. Microscopic measurements of individual particles do not correspond exactly with other determinations. In this case all the diameters measured were greater than the average of the group as determined by the air permeation method. The particles in the 12 micron fraction ranged from 12-25 microns and the 1.1 micron fraction particles were all below 4 microns in diameter. The surface areas of the three fractions were 850, 1,550 and 17,000 cm. <sup>2</sup> per gram, respectively. These tests were made on Mexican bean beetle and paris green was used on bean foliage. It is impractical of course to use paris green on bean foliage under practical conditions as it causes injury. Also the Mexican bean beetle may have certain disadvantages as a test insect for this type of test.

Another factor developed. Paris green is not made up of solid particles but groups of crystals, so we had to stir the different fractions for different periods to get equal dispersions. There seems to be a number of factors that come into the picture when making particle size studies. Stirring might have had some grinding effect.

Feeding was directly proportional to the particle size and mortality inversely so. Mortality was 29, 40 and 53% for the sprays, and 42, 61 and 88% for the dusts, in the order of decreasing particle diameter. The mortality increased as the particle size decreased. For the coarse fraction we found there were 208 mg. of insecticide consumed per gram of insect, for the medium 121 mg., and for the fine 35 mg. in the spray tests. The dust tests ran 449, 238, and 34 mg., respectively. Talc gave 4,841 mg. consumed and 19% mortality. These data might lead to the conclusion that the finer the particles the better, but this might not hold in practice. At the recent entomological conference in Urbana a report was given on mosquito larvicide treatments using paris green. When the dust was applied from an airplane only a relatively small percentage of the finest material actually fell on the area which they were treating. The loss from air drift was large. With a coarser dust they found that the recovery was up, indicating that the coarser material could be applied more efficiently. There is usually some extremely fine material present when an insecticide is ground so that it will pass a No. 200 screen. This may be largely wasted when applied as a dust, if air currents carry it away.



## 5. The Relation of Particle Size to Efficacy

### "Aerosols"

By E. R. McGovran

These tests with liquefied gas aerosols were conducted by Mr. Fales. The solutions used were pyrethrum extract and sesame oil in Freon. Different size openings and different types of nozzles were tested. This may not be a particle size problem but seems to be related to it. We used a Westinghouse capillary tube, which is .017 inch in diameter. It gave 75% kill of houseflies. The .03 inch capillary gave 73% kill. The oil burner nozzle which had the smallest opening gave 39% kill. When Dr. Goodhue ran settling rates on these they were all the same. This indicated that some factor other than the size of the particles was operating. Also we ran tests using 2, 4, and 8 inch lengths of capillary. Here again there was some variation (72, 66, and 59% respectively) in the mortality obtained but the settling rate was just the same. However, the rate of delivery was about twice as rapid for the short as for the long tube. We haven't been able to demonstrate that this is particle size relationship but it seems that particle size may be involved.

Further tests using small dispensers, with openings .0225, .018, and .0135 inches in diameter gave kills of 83, 82, and 53%, indicating the same type of thing, that kill begins to fall off when the opening is too small.

Another phase of the work which is correlated is shown by variations in the amount of nonvolatile material. As the nonvolatile goes up the particle size increases. These tests were made using pyrethrum extract and sesame oil in a Freon aerosol. Two percent nonvolatile killed 2% of the houseflies. Doubling it to 4% killed 10%, doubling this to 8% killed 38%, and doubling this to 16% nonvolatile killed 62%. The relationship between percentage of nonvolatile material, which controlled particle size, and the kill is obvious. These solutions were dispensed through the same dispenser and had about the same pressure.

To determine the optimum range, solutions were tested containing 30%, 15% and 7.5% nonvolatile. These caused 42%, 54% and 37% mortality, respectively. The range was then narrowed to 20%, 15% and 10% nonvolatile. Forty-seven percent, 73% and 61% mortality, respectively, was obtained. These tests were made on houseflies.

On *Aedes* mosquitoes 20%, 13.5% and 10% nonvolatile in a pyrethrum-sesame oil-Freon aerosol solution caused 52%, 57% and 71% mortality, respectively. From this it appears that the particle size produced by 10% nonvolatile was more effective than larger particles against mosquitoes, although against houseflies slightly larger particles were found best.

## 5. The Relation of Particle Size to Efficacy

By R. E. Gray, Agricultural Engineering

Working on the machinery, we have attacked the problem from three angles--the abrasion standpoint, the separation, and the performance of the machine.

The study is quite illuminating in that it shows that if the diluent is not properly selected to go with the poison there is considerable separation and it becomes very ineffective. One of the larger machinery manufacturers mentioned the fact that he had boll weevil applicators that blew material out over twenty rows and only had control of the first three rows, indicating considerable separation. It has been found that the finest material does not seem to produce much abrasion. When the material was larger it seemed to be more abrasive. Abrasion did not depend on the finer but on the larger size. In working out the combinations of diluents and poisons there will be less separations. The work on particle size is directly related to the work we are doing, in the design of distributing mechanism as well as the area of the tubes.

## Economics of Particle Size

By U. C. Loftin

Micronized sulfur when used to control cotton flea hopper gave about twice the mortality and worked much better in the field than ordinary dusting sulfur, but it cost as much to micronize the sulfur as it did to use larger quantities of the other sulfur. Therefore nothing was gained by using micronized material.



## 5. "Aerosols" The relation of particle size to efficacy

By Randall Latta

Dr. McGovran pointed out that the optimum particle size is around 10 microns in diameter. Our problem is to increase the particle size of thermal generated aerosols upwards from that existing in screening smokes to as near this optimum as possible.

A particle size of 10 microns has sufficient volume to produce quick killing, apparently because only one or a few particles are necessary. Its rate of fall is not great so that it will stay suspended in the air for a considerable period. Biological results also indicate that the contact of the particle with the insects is very good. On the other hand, screening smoke sized aerosols with particles around 1 micron require a much longer exposure period to be effective, apparently because of the large number of particles that are needed to contact an insect to produce mortality. The rate of fall of these smaller particles is so slow that they remain suspended for long periods and permeate all areas--a factor which may have considerable importance. It has been proven that particle sizes of 1 micron or less were effective but as pointed out above the period of exposure must be much longer than with larger particles.

The relative effectiveness of different particle sizes was demonstrated in a series of tests made by the Columbia University group of N. D. R. C. at our Beltsville laboratory. These tests showed that larger particles required a very short exposure period as compared to small size when approximately the same volume of material was used. For instance, particles of 8.6 microns in diameter killed all mosquitoes in 1 1/3 minutes exposure at a given concentration. On the other hand, particles of .72 microns required 30 minutes at approximately the same concentration.

In our tests with thermal generated aerosols we have been able to get 100% kill of different insects--such as aphids, termite larvae, flies, mosquitoes, thrips, and tent caterpillars--with aerosols of pyrethrum, DDT, and nicotine. With increased concentrations it was possible to kill these insects in periods from 10 seconds to 2 1/2 minutes.

## 5. "Aerosols" by L. D. Goodhue

In our liquefied gas aerosols doubling the concentration did not double the particle size. It only increased the particle size about 1.2. Particle size in aerosols is not critical.



6. Field problems involving particle size of insecticides and fungicides (dustability, adhesion, separation of diluents, etc.) - general discussion

By C. M. Smith

There are many difficulties in preparing samples. It requires a lot of thought so that the conclusions are quite distinct.

By W. H. White

We have been calling materials mixed with insecticides "diluents." Maybe they should be called "carriers." The term "dispersing" also has been suggested.

By J. W. Roberts, Plant Industry

We have been interested in the fineness of particles of sulfur. We have always considered one important thing, that fineness affects tenacity and also distribution on plants was important. We have to have a cover that will catch anything that happens our way.

In November 1943, Gold published on different sulfurs and methods of estimating particle sizes.

7. What can be done to accelerate and improve investigations relative to particle size? - general discussion

By R. G. Richmond

It has been unanimously shown that discussions should be continued. Perhaps a committee might do well to review the notes of this meeting and think over the matter and take some steps to formulate a program of research and clear up some points. It is obvious that this work will be continued and we should decide whether we are covering all the field.

By H. L. J. Haller

Specificity of insecticides should be considered, as well as the specific insect to be controlled. There should be more discussion on the question of segregation and particularly the relation of organic insecticides when diluted with pyrophyllite or talc. There has been great difficulty in determining the particle size of organic compounds when diluted with an inorganic material like talc, etc.

Greater consideration should be given to the relative specific gravity of organic insecticides and inorganic diluents, as there is a tendency toward a segregation of the insecticide and the diluent.

